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PRACTICE EFFECTS, KNOWLEDGE OF RESULTS AND TRANSFER IN PITCH DISCRIMINATION

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ABSTRACT

PRACTICE EFFECTS, KNOWLEDGE OF RESULTS AND TRANSFER IN PITCH DISCRIMINATION

The effect of practice on the ability of Ss to discriminate differences in pitch between two sounds (difference thresholds or DLs) was investigated using four different experimental groups. These four groups differed in regard to the frequency at which training was given (800 or 3,000 cps), and whether or not knowledge of results was given. All discriminations were made against a white noise background. Training was given to all experimental Ss for four successive days with a fifth day devoted to both practice and a transfer test. The daily procedure consisted of listening to three tapes, each requiring 100 discriminations. A modified descending staircase procedure (method of limits) was utilized in obtaining the difference threshold. The main findings were: (1) a negatively accelerated, declining curve of DLs for all four experimental groups with the largest drop taking place within the first day or two for most Ss, (2) discrimination was slightly better with knowledge of results than without, but not significantly so, and (3) the surprising fact that a net negative transfer of training effect was revealed when the transfer was attempted between the two different points on the frequency spectrum utilized here. Implications for auditory training procedures are discussed.

FOREWORD

Purpose

Usually trainees when subjected to practice in learning pitch discrimination show improvement. However, the extent of this improvement and the training and stimulus variables involved are far from clear. Since much of the work in this area was done prior to the development of modern auditory procedures some experimental investigation using modern techniques was considered appropriate. This study, then, represents an initial attempt to measure the shift in sensitivity of pitch discrimination and some of the factors which influence this shift.

Results

Among the findings discussed in detail in the report are the following:

(a) The minimum difference between pairs of stimuli that could be perceived as being different (DLs) was in the shape of a negatively accelerated declining curve.

(b) Knowledge of results did not significantly differ from no knowledge of results in forming discriminations.

(c) There was a negative transfer effect. The control group which had only two trials before transfer tended to show greater transfer than the experimental groups which had 12 trials.

Implications

The implications for training in the auditory mode (if these results are confirmed) is that feedback (knowledge of results) will generate positive, neutral or negative effects depending whether or not the trainee is overloaded in his information processing capability. Also, establishing a set which is detrimental to transfer must be carefully controlled so as not to impair flexibility in transferring from one particular frequency to another.

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INTRODUCTION

Although there is some evidence of the effect of practice on increasing the proficiency of subjects (Ss) in pitch discrimination (Wyatt, 1945), the size of the shift in sensitivity with practice, the reason or reasons for the shift and the training and stimulus variables which control this shift are far from clear. Partly, this is due to the differences in methodology and procedures used by the various workers in the field, and partly this is the result of the fact that most of the work in this area is dated, i.e., was done prior to the development of modern techniques and methods in the analysis of audition. As a result, the work on the problem of relating stimulus and practice parameters to increased sensitivity of frequency or pitch discrimination is far from complete. The one recent experiment in the area is an exploratory attempt by Campbell and Small (1964) to study the effects of practice and feedback on frequency discrimination. In summary these authors found a negatively accelerated, declining curve of DLs, no change in their Ss' median constant errors and surprisingly, a negative relationship between feedback and performance. However, their design confounded practice and feedback variables throughout most of their experimental sessions, so that they found it difficult to evaluate the relative effects of each. The experiment reported in this paper permits a direct statistical analysis of the contributions of practice and feedback to the DL shift reported by those authors and also hypothesized here. This was accomplished by using separate groups to evaluate the role

of feedback rather than having the same Ss receive practice with and without feedback as Campbell and Small (1964) did. In addition, their work is extended by utilizing two new points on the frequency spectrum as the standard tone (800 and 3,000 cps), and by an investigation of transfer effects from practice at one frequency to performance at another. Campbell and Small used a single standard of 1,000 cps throughout their experiments and did not attempt to analyze transfer effects.

METHOD

Experimental Groups

The 64 experimental Ss were divided into four groups of 16 on the basis of the frequency on which training was given (800 or 3,000 cps), and whether they received knowledge of results (KR) or no knowledge of results (NOKR) during the training sessions. Thus, there were two 800 cps groups: one with KR and the other with NOKR. Similarly, of the two 3,000 cps groups, one was given practice with KR and the other with NOKR.

Training Days

All experimental Ss received practice for 4 days with a fifth day devoted to both practice and a transfer test. The five days always occurred successively, beginning on Monday and ending Friday. Each day's session lasted approximately 1 to 1 1/4 hours during which time each S listened to 3 tapes. The stimulus content of these tapes will be described in detail below. All Ss were run at the same daily

time during the experimental week. This design allows a 4 (days) X 3 (trials) X 2 (KR vs. NOKR) X 2 (800 vs. 3,000 cps) repeated measures analysis of variance.

Transfer Day

On the fifth day all experimental Ss continued to receive training at their regular frequency for two tapes, but these tapes were in each case with NOKR. Actually, this involved a change in stimulus tapes only for the KR groups; the two NOKR groups continued to receive their customary NOKR tapes. Finally, the third tape given on the fifth day constituted a transfer of training test. Ss who had been receiving training at 800 cps whether with or without KR were now tested on a 3,000 cps NOKR tape. Conversely, Ss who had been trained at 3,000 cps were now given a discrimination test utilizing a sound of 800 cps as the standard.

Control Groups

Two control groups were run. Each group consisted of 16 Ss selected from the same population as the experimental Ss. The procedure for the two control groups paralleled the fifth day's treatment of the experimental groups. Thus, Control Group A received tapes with NOKR. The first two measured DLs against an 800 cps standard, while the third tape did the same against a 3,000 cps standard. Note that this is exactly the fifth day's treatment of the two 800 cps experimental groups. Control Group B also received

three tapes with NOKR. But the first two tapes for this group measured DLs against a 3,000 cps standard while the third tape did so against an 800 cps standard. Again note that this is exactly the fifth day's treatment of the two 3,000 cps experimental groups. Table 1 schematizes this set of relationships.

Subjects

The Ss were male undergraduate volunteers enrolled at C. W. Post College. The criterion for selection was normal hearing as determined by testimony and a simple screening test utilizing a commercially available audiometer. A hearing loss of more than 15 db was sufficient grounds for exclusion from the experiment as was extensive musical experience (school band, orchestra, etc.). All Ss were paid at the rate of $1.00 per hour, and experimental Ss committed themselves to 5 consecutive daily sessions lasting approximately 1 to 1 1/4 hours. In addition, they were informed that a bonus of $1.00 would be awarded to the S who produced the best single performance of the week and also to the S who showed the most improvement for the week. Subjects were typically run in small groups ranging in size from 2 to 4 although some were run individually.

Apparatus

Since the psychophysical procedure involved a comparison between a standard and comparison tone, two audio-generators were used. The standard tone input was from a Hewlett-Packard Signal Generator, Model # 205AG. The comparison tone input was provided by a General

Table 1

Schematized Design of Control Groups A and B*,

Indicating Standard Frequency for Each Trial.

N = 16 in each group

	Trial 1	Trial 2	Trial 3
Control Group A	800 cps	800 cps	3,000 cps
Control Group B	3,000 cps	3,000 cps	800 cps

* Note - Control Group A's Treatment is identical to the 5th day's treatment for both 800 cps experimental groups, while Control Group B describes the 5th day's treatment for the two 3,000 cps experimental groups.

Radio Beat Frequency Audio-Generator, Model # 1304-B. A white noise background was supplied by a Grayson-Stadler Noise Generator, Model # 455-B. The tapes were recorded on an Ampex Studio Recorder, and were played back to the Ss on a Fairchild Tape Recorder.[1] The Fairchild was attached to four monaural earphones via a 4 position distribution box with a provision for monitoring by the operator. The audiometer used to screen the Ss hearing was the Maico Model # Ma2B, Special.

Stimulus Material

Three separate tapes were constructed for each of the 4 experimental conditions giving a total of 12 stimulus tapes. Each S was given 3 tapes per day, the order being randomized within a given day. This was done in an attempt to minimize the learning of response sequences by Ss.

Instructions

The KR tapes all contained the following instructions: "You will be presented with a series of tones, one tone followed by a second. The second tone will be higher or lower in pitch than the first. At the appropriate place on your answer sheet you are to cross out the H for higher if the second tone was higher than the first, or L for lower if it was lower." The NOKR Ss had the same instructions read to them at the beginning of each daily session.

1 The tapes were run at a speed of 15 inches per second.

Tape Construction

The above instructions reflect the modified descending staircase procedure (method of limits) which was employed in obtaining our DLs. In order to understand this procedure a detailed description of the stimulus material follows. There were 100 pairs of tones on each of the 12 tapes. A pair consisted of the standard (.3 sec. in duration) followed by a variable (.3 sec.). There was a short temporal gap between the standard and variable (.1 sec.) while a longer period separated each pair of tones (6.0 sec.). The frequency of the standard tone was always constant throughout the course of any given tape being either 800 or 3,000 cps. The variable tone's frequency changed during the 100 pairings on any given tape. The frequency difference between the standard and variable tones was greatest at the beginning of each tape and successively narrowed during the course of 100 trials.

In order to accomplish this systematically, the 100 pairs of tones, or trials, were broken down into ten divisions of ten pairs each. Within each of the ten divisions the frequency difference between the standard and variable was constant, although in five of the ten trials within a division, the variable tone was lower than the standard and in five it was higher. The placement of the five higher and five lower trials within a division was randomized with the provision that maximum repetition was limited to either three higher or three lower comparisons. This limit was imposed to avoid the development of counter sets on the part of the Ss. Three such

random sequences of trials were selected; the same three sequences were used in constructing the tapes for all four experimental groups. Thus, the six 800 cps tapes had variable tones which deviated from the standard 800 cps tones in a randomized, up-down fashion in ten blocks or divisions each containing ten trials or comparisons. The frequency difference between the standard and variable tones on the first block of ten trials was 25 cps and on succeeding blocks progressively diminished to 20, 17.5, 15, 12.5, 10, 7.5, 5, 2.5, and 1.0 cps. In a similar fashion, on the six 3,000 cps tapes the frequency difference between the standard and variable tones on the first block of ten trials was 70 cps and then was progressively diminished to 60, 50, 40, 30, 25, 20, 17.5, 15, and 10 cps.

On the KR tapes the subject was informed which of the two possible responses was correct, i.e., higher or lower. This was accomplished verbally on tape toward the end of the 6.0 sec. interval between the pairs of tones. In order to prevent gross errors in placement of the responses by the _S_s over the course of 100 pairings, the trial number was given every fifth trial to all _S_s in all conditions. All signals were embedded in a white noise background designed to mask outside disturbances. This white noise was at a 50 db intensity level; the signals exceeded the background white noise by 10 db.

RESULTS

Practice Effects

Each S's DL for each trial was computed where possible by simple linear interpolation. In approximately 15 per cent of the trials where the data were too irregular for this method, computation was by the averaged z-score method (Woodworth & Schlosberg, 1954).

Figure 1 shows the mean DL for each trial on the first four days for the four experimental groups. The analysis of variance performed on these data is summarized in Table 2. The improvement both between days and within days, as generally evident in the curves presented in Fig. 1, is highly significant, as is the difference in performance between groups practicing with the two standard frequencies. The curves consistently show lower mean DLs for each KR group than for its corresponding NOKR group, but the F for KR is not quite significant at the .05 level. However, the significant interaction of KR with days and frequencies reflects the finding that with the 3,000 cps standard tone KR provides an initial advantage which decreases daily, but that the effect of KR on performance with the 800 cps standard is slight and fairly consistent from day to day.

Some other features of the data are borne out by significant interactions. The two 3,000 cps groups show more rapid improvement between days and within days than the two 800 cps groups. The slope of the within days curve, however, tends to decrease with successive practice days, this relationship being greater for the 3,000 cps groups than for the 800 cps groups.

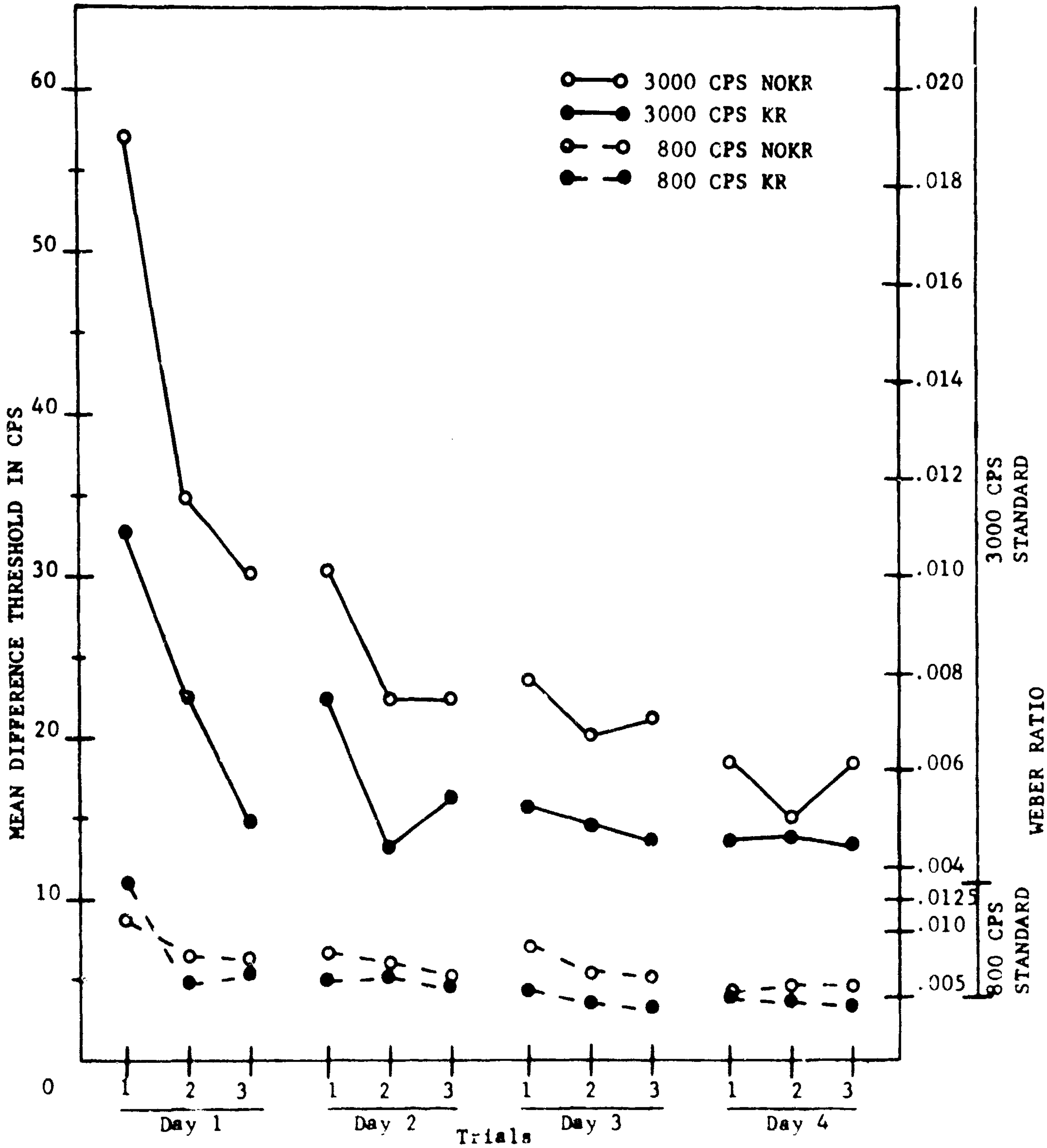

Fig. 1 Mean DL per trial on the four practice days for the four experimental groups. Also indicated is a Weber-ratio scale for each standard frequency.

Table 2

Analysis of Variance of DLs of Three Trials on Each of Four Practice Days for the Four Experimental Groups

Source	df	MS	F
Between Ss	63		
Frequencies (A)	1	52,668.75	44.58**
KR (B)	1	4,246.92	3.59
A x B	1	2,566.69	2.17
Error (between)	60	1,181.53	
Within Ss	704		
Days (C)	3	3,424.47	29.05**
Trials (D)	2	2,088.00	17.71**
A x C	3	1,729.40	14.67**
A x D	2	1,031.26	8.75**
B x C	3	388.06	3.29*
B x D	2	12.98	
C x D	6	596.06	5.06**
A x B x C	3	527.16	4.47**
A x B x D	2	44.83	
A x C x D	6	334.81	2.84**
B x C x D	6	46.32	
A x B x C x D	6	112.80	
Error (within)	660	117.88	
Total	767		

* $P < .05$

** $P < .01$

Transfer Effects

Figure 2 shows the performance of the two NOKR groups on their very first trial, the performance of all four experimental groups on the fifth day and the performance of the two control groups. For three of the four experimental groups, the mean DL on the third (transfer) trial is lower than the mean DL on the initial (first day's) trial for the comparable NOKR groups. Only for the 800 KR groups (with the transfer trial at 3,000 cps) is the difference significant at the .05 level ($\underline{t} = 2.064$), with the difference for the 800 NOKR group just missing significance ($\underline{t} = 2.037$). In both these cases, the transfer trial performance is better than that on the initial trial at 3,000 cps. At each frequency, however, the control group has a lower mean DL than either experimental group, each control DL being significantly lower than its corresponding first trial DL: with the 800 cps transfer trial, $\underline{t} = 2.113$, $\underline{P} < .05$; with the 3,000 cps transfer trial, $\underline{t} = 3.062$, $\underline{P} < .01$.

For neither frequency do the differences among the three transfer trial DLs yield a significant $\underline{F}$, but this is not the most appropriate comparison from which to infer transfer effects. First, the 3,000 cps control and 3,000 cps NOKR groups were not equal in initial performance; the DLs on the first two trials given the 3,000 cps control group were lower than those on the first two trials of the first day for the 3,000 NOKR group ($\underline{t} = 3.248$, $\underline{P} < .01$). Secondly, the performance immediately preceding the transfer trial varied at

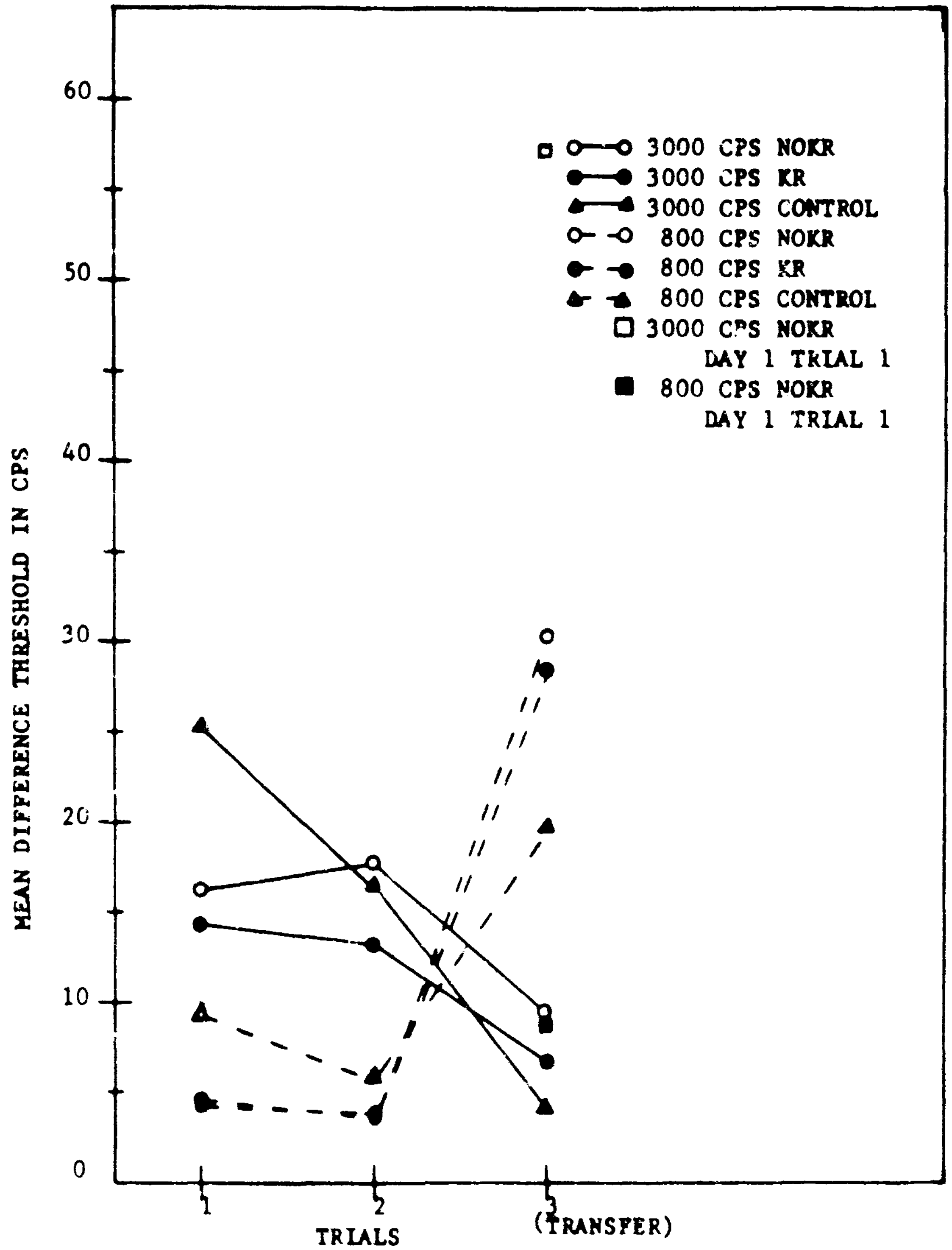

Fig. 2 Mean DL per trial on the transfer day for the four experimental groups and the two control groups. Also shows mean DL on the initial trial (first day) for the two experimental NOKR groups.

each frequency as a function of the experimental treatments. Consequently, comparisons on the transfer trial alone might reflect these variables in addition to transfer effects.

A more appropriate comparison was made, adjusting the transfer data in terms of performance levels preceding the transfer trial. The difference was found between the mean of the first two trials shown in Fig. 2 and the third (transfer) trial. The signs of these differences were made parallel for the two frequencies as follows: in the 3,000 cps groups, where the transfer trial employed the 800 cps standard, a drop in DL was made positive in sign, and a rise, negative; in the 800 cps groups, a rise in DL was made positive and a drop negative. Since, for a given level of performance before the shift, the lower the DL on the transfer trial, the greater the amount of positive transfer, in the 3,000 cps groups a large difference indicates a large transfer effect, while in the 800 cps groups a small difference indicates a large transfer effect. The mean difference in each of the six groups appears in Table 3. A 2 x 3 analysis of variance using the parallel-signed difference scores is summarized in Table 4. Note that for each frequency the control group shows a larger transfer effect than either of the corresponding experimental groups, the latter two groups performing at about the same level. This apparent relationship is confirmed by the significant interaction between frequencies and conditions. Further analysis with *t*-tests indicate significant comparisons involving the 800 cps control group with the 800 cps KR group ($t = 2.156$, 90 *df*,

Table 3

Mean Shift in DL (in cps) from First Two Trials to Third Trial on Transfer Day for the Four Experimental Groups and the Two Control Groups

Shift in Standard Freq.	Exper. KR	Exper. NOKR	Control
3000 cps to 800 cps	6.97	7.41	16.88
800 cps to 3000 cps	24.59	26.19	12.28

Table 4

Analysis of Variance of DL Shifts from First Two Trials to Third Trial on Transfer Day for the Four Experimental Groups and and the Two Control Groups

Source	df	MS	F
Training Condition	2	39.45	
Standard Frequency	1	2704.07	10.38**
Interaction	2	1390.29	5.34**
Error	90	260.54	
Total	95		

** $\underline{p} < .01$

$P < .05$), and with the 800 NOKR group ($t = 2.436$, 90 df, $P < .05$). Similar comparisons with the 3,000 cps groups yielded t-values at about the .10 level. However, at each frequency the difference between the two experimental groups fails to approach marginal significance.

The within days improvement previously referred to ($P < .01$) is reflected in an analysis of the mean within day or daily transitions between trials of the four experimental groups (but excluding the fifth or transfer day). This revealed that of 32 such transitions, 24 (75%) showed at least some minimal improvement. One may also examine inter-day transitions to determine if there was any appreciable back-sliding or warm-up decrement from the last trial on a given day to the first trial on the subsequent one. Again using only the first four experimental days, there are 12 transitions from the last trial of one day to the first trial of the next one. Of these 12 transitions, six (50%) showed some minimal, mean improvement, while six (50%) showed some decrement. Of the six transitions which showed a decline in sensitivity, three occurred between Day 1 and Day 2, two occurred between Day 2 and Day 3, and only 1 occurred between Day 3 and Day 4. From this analysis and from an examination of the curves presented in Fig. 1, we may conclude that there is a tendency for some back-sliding or loss of sensitivity to occur from day to day, especially in the early phase of training.

DISCUSSION

In support of one of our hypotheses, and confirming the work of Campbell and Small (1964), we find a negatively accelerated, declining curve of DLs for all four experimental groups. One characteristic of this shift is that it occurs rather rapidly, the biggest drop taking place within the first day or two for most Ss. These general effects of controlled practice on performance in sensory or perceptual tasks are in agreement with the majority of reported findings in the literature (Gibson, 1953). The problem remains, however, that the generality of these findings explains neither what is taking place psychologically to improve the S's sensitivity, nor the specific training conditions which will yield optimal shifts. Also, the fact that negative transfer effects as a result of training are reported both here and in Gibson's (1953) survey of the literature suggest the importance of a more detailed analysis of these relationships than has occurred to date. As to what are the underlying set of dynamics which mediate these changes in sensitivity, a number of hypotheses have been advanced by individuals working in the area. A characteristic list of these hypotheses might, for example, include references to attitude, set or attention, reinforcement, stimulus differentiation, habituation or skill acquisition, signal detection theory, feedback or knowledge of results and neurological sensitization. Unfortunately, no single one or combination of the above positions has been generally accepted by a substantial percentage of the professionals who concern themselves

with these matters.

With the above problems in mind it is of interest to note that the Ss in the experiment reported here not only benefited significantly from their practice over a series of days, but also showed positive effects for practice occurring during the course of a single day. This later fact combined with the finding that there is some tendency for a loss of sensitivity to occur between days, especially in the early phase of training, would tend to suggest that where these skills are used in performing operational tasks, short daily warm-up sessions may be necessary to achieve maximum efficiency levels. This would apply especially to new and relatively unskilled personnel, and also to older hands whose skills have not been utilized for extended periods of time. Indeed, a careful measurement of decline in proficiency over time from pre-established operational norms could provide a convenient calendar indication for retaining on such widely used skills as markmanship, radio operation, sonar operation, etc. Such data would also be helpful in determining that level of training most resistant to a significant decline, and yet at the same time realistic in terms of the cost of such training.

When attention is turned to the effects of knowledge of results on performance, the consistent differences in mean scores in favor of the two KR groups over their NOKR counterparts unfortunately do not reach significance at the .05 level although a trend exists ($P < .10$). These results thus fail to support conclusively the original hypothesis concerning the beneficial effects of KR during practice,

but they do differ from the previously cited findings of Campbell and Small (1964). It will be recalled that these authors, much to their surprise, report that Ss who did not receive KR on their first trial actually performed at a superior level during the course of their experiment. One possible explanation of this result might be the manner in which feedback was supplied to their Ss. After indicating their response by depressing a "higher" or "lower" button, a "right" or "wrong" light flashed on followed by a warning light and the next trial. As their total intertrial interval was only about 1.25 sec., it is suggested here that the information processing capacity of the S may have been overloaded under these conditions of stimuli presentation and feedback with a consequent detrimental effect on actual performance. This analysis suggests that the actual conditions under which feedback is given may be quite critical in determining whether the feedback will generate positive, neutral, or negative effects. In addition, as noted in the introduction, the Campbell and Small design makes it difficult to separate the effects of practice from feedback since both experimental groups received the same series of NOKR and KR trials subsequent to the first one.

The transfer data reported here, i.e., the effects of practice in pitch discrimination with one standard frequency on performance with the other frequency, are not at all impressive. The comparison of DLs on the transfer trial (fifth day, third trial) with those on the very first trial on the first day for the corresponding NOKR groups show the former to be either no better or barely significantly

better than the unpracticed performance level. What is more, a sensitive comparison of the transfer effects of the experimental and control groups indicate that the controls, who have had only two trials before the transfer trial tend to show greater transfer effects than the experimental groups.

The comparison, within each frequency, of each experimental group with the control group approximates the classical paradigm for assessing transfer effects:

Experimental group:	Task A	Task B
Control group:	- - - -	Task B

On this basis, the interpretation of the results is that the four days of practice with one standard frequency produces a net negative transfer to the other frequency. This surprising outcome can perhaps be best explained by assuming that the four days of practice with the first frequency produced a set peculiar to (and facilitating performance under) the conditions of that practice, which inhibited performance under other conditions, i.e., at the other frequency. The control groups received just enough practice at the first frequency to orient them to the general conditions of the task, without impairing their flexibility. Interestingly, discrimination on the transfer trial for both control groups is significantly better than the unpracticed performance, implying that a minimal degree of orientation accomplishes what a greater degree of practice does not.

The above findings taken together suggest the possibility that, as regards transfer effects, two opposing processes are operating in the experimental groups. The initial trials seem to have the effect of adapting S to the experimental situation, producing a general facilitation in his performance of the task, and a disposition toward positive transfer. Additional practice, however, while it further improves task performance, produces a rigid orientation to the specific stimuli employed in the task, disposing S toward negative transfer when the stimulus pattern is altered sufficiently.

The highly significant difference between frequencies on the four practice days is to be expected, and merely confirms Weber's original observation that the absolute size of any difference threshold will reflect the value of the standard used. However, Weber ratios based on the mean DLs yield certain interesting observations. (see Fig. 1). First, although the ratios for the four groups on Trial 1 of Day 1 range approximately from .010 to .020, they rapidly decline until, by the fourth day, the ratios for all groups are on the order of .005. This decline in the Weber ratio roughly from 1/4 to 1/2 its original value is another indication of the magnitude of threshold shifts obtainable as a result of practice.

Secondly, despite the differences in magnitude of the DLs obtained with the two standard frequencies, the Weber ratios for the two frequencies are extremely close, especially on the third and fourth days of practice. This, of course confirms Weber's Law for the two frequencies used here.

Finally, it is interesting to compare the Weber ratios reported here with those obtained by previous investigators. Harris (1952) and Woodworth and Schlosberg (1954) indicate that for those frequencies as used in this experiment, a range of ratios exists with values of approximately .002 to .004 for practiced Ss. The similarity of these ratios to those obtained on the fourth day (.005) would seem to indicate the general validity of the procedures used in this study.

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13. ABSTRACT

The effect of practice on the ability of Ss to discriminate differences in pitch between two sounds (difference thresholds or DLs) was investigated using four different experimental groups. These four groups differed in regard to the frequency at which training was given (800 or 3,000 cps), and whether or not knowledge of results was given. All discriminations were made against a white noise background. Training was given to all experimental Ss for four successive days with a fifth day devoted to both practice and a transfer test. The daily procedure consisted of listening to three tapes, each requiring 100 discriminations. A modified descending staircase procedure (method of limits) was utilized in obtaining the difference threshold. The main findings were: (1) a negatively accelerated, declining curve of DLs for all four experimental groups with the largest drop taking place within the first day or two for most Ss, (2) discrimination was slightly better with knowledge of results than without, but not significantly so, and (3) the surprising fact that a net negative transfer of training effect was revealed when the transfer was attempted between the two different points on the frequency spectrum utilized here. Implications for auditory training procedures are discussed.

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